METHOD FOR LOCATING THE MECHANICAL AXIS OF A FEMUR

FIELD OF THE INVENTION

[001] The invention relates to the field of computer-assisted surgery. More specifically, it relates to determining the mechanical axis of a femur and the center of a femoral head of femur during computer assisted surgery.

BACKGROUND OF THE INVENTION

[002] While Computer-Tomographic(CT)-based Computer Assisted Surgery (CAS) systems are widely known in the art, CT-less CAS systems are slowly emerging as the technology of choice for North America and Europe. It is desirable to cut down the pre-operative time a surgeon must spend to prepare a surgery. It is also desirable to provide applications that can use other media than CT-scans, when these are not available. The CT-less system reduces pre-operative time and instrument calibration time, especially in simple surgeries, and in the case of more complex surgeries, the CT-less system can be combined with CT-based applications.

[003] A CT-less intra-operative bone reconstruction system advantageously provides a surgeon with visual confirmation of the tasks he is performing during the surgery. In pending US patent application 10/345,403 to the present applicant, there is described a method and system for intra-operatively presenting an approximate model of an anatomical structure by collecting a cloud of small surfaces. The cloud of small surfaces is

gathered with a registration pointer having an adapted tip capable of making contact with the surface of an anatomical structure and registering the normal at the point of contact. Reconstructing and registering anatomical structures intra-operatively is at the core of CT-less CAS systems.

[004] When performing surgery to the lower limbs, it is important to determine the mechanical axis of the leg. The mechanical axis refers to the axis formed by a line drawn from the center of the femoral head to the center of the knee joint and a line drawn from the center of the knee joint to the center of the ankle joint. In perfectly aligned leg, the mechanical axis forms a straight line.

[005] Determining the mechanical axis of a leg comprises locating the center of the femoral head. It is known in the art of computer-assisted surgery to locate the center of the femoral head by dynamically registering the relative position of the femur while rotating the proximal end in a circular pattern. However, this technique is vulnerable to noise, thereby affecting the quality of the readings by the position sensing system. The level of accuracy obtained also varies depending on how long the rotation is maintained for and with how much precision the system can register the points while the bone is in motion. Furthermore, the motion of the femur for the registration process may cause the hipbone to move and this can introduce further errors into the measurements.

[006] Detecting the femoral head is a crucial process that will influence the end result of the surgery. There is therefore a need to develop a system and method of femoral head detection that overcomes the drawbacks of the state of the art and guarantees a certain level of accuracy.

SUMMARY OF THE INVENTION

[007] Accordingly, an object of the present invention is to overcome the influence of noise for tracking devices and improve accuracy when locating the center of the femoral head of a femur.

[008] According to a first broad aspect of the present invention, there is provided a method for determining a mechanical axis of a femur using a computer aided surgery system having an output device for displaying said mechanical axis, the method comprising: providing a position sensing system having a tracking device capable of registering instantaneous position readings and attaching the tracking device to the femur; locating a center of a femoral head of the femur by moving a proximal end of the femur to a first static position, acquiring a fixed reading of the first static position, repeating the moving and the acquiring for a plurality of static positions; and locating the centre by determining a central point of a pattern formed by the plurality of static positions; digitizing an entrance point of the mechanical axis at a substantially central position of the proximal end of the femur; and joining a

line between the entrance point and the center of rotation to form the mechanical axis.

[009] Preferably, the system automatically registers instantaneous positions periodically and averages a plurality of the instantaneous positions to determine a static position.

BRIEF DESCRIPTION OF THE DRAWINGS

[010] These and other features, aspects and advantages of the present invention will become better understood with regard to the following description and accompanying drawings wherein:

[011] FIG. 1 is a flowchart of the preferred embodiment of the invention;

[012] FIG. 2 shows the center of the femoral head on the user interface;

[013] FIG. 3 shows the mechanical axis on the user interface;

[014] FIG. 4 shows the mechanical axis and the epicondylar axis on the user interface;

[015] FIG. 5 shows the mosaic reconstruction of a bone; and

[016] FIG. 6 is a diagram of a digitizing tool with an adaptive tip;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[017] In a preferred embodiment of the invention, a Polaris™ optical camera is used with a Navitrack™ system sold by Orthosoft, Inc. A femoral tracker is optimally placed at an anterior position with respect to the sagittal anatomical axis and a lateral position with respect to

the frontal anatomical axis. Ideally, the anterior position should be about 45 degrees and the lateral position should be about 10 degrees. The position to optimize accuracy for the bone trackers is about 12 cm from the knee joint facing the camera.

[018] Figure 1 is a flowchart describing the steps used to determine the mechanical axis of the femur bone during surgery. The first step is to provide a position sensing system having a tracking device capable of registering instantaneous position readings and attaching the tracking device to the femur 16. The next step is to locate the center of the femoral head 17. This point will be used in calculating the mechanical axis. To locate the center of the femoral head, the proximal end of the femur is placed in a first static position. A fixed reading of the first static position of the femur is acquired by the position sensing system. This action is repeated for a plurality of static positions. The center of the femoral head is then located by determining a central point of the pattern that is formed by the plurality of static positions. Also needed to calculate the mechanical axis is locating the entrance point of the mechanical axis 18. This point is in the notch found at the femoral distal end of the femur bone, and matches the intra-medullar rod entrance point, which surgeons are familiar with. The surgeon attempts to locate this point by physically palpating the area and once the center is located, this point is digitized by the digitizing tool and recorded in the

memory of the system. Once the two end points have been identified, a line is formed to join them together and create the mechanical axis 19. The axis is then displayed on an output device to visually assist the surgeon throughout the surgery.

[019] The detection of the femoral head is ideally performed by taking fourteen static points of the femur with respect to a fixed pelvis. That is to say, the pelvis must remain fixed throughout the acquisition of each point until the end. Each acquisition of a static point should be done by immobilizing the tracked leg on the operating table and waiting for an indication that the system has registered the position. This indication may be visual on the output device, or an audio signal such as a beep emitted by the system. Alternatively, the surgeon can take anywhere between 7 and 20 positions. The surgeon can choose to use a pelvic reference or not, and by doing so, increases the algorithm accuracy by recording the small oscillation movements of the pelvis during the acquisition.

[020] The surgeon should take points that would best fit a conical pattern with the femoral tracker. The pelvis and the optical camera should stand immobile during the whole process to reach a good level of accuracy. Between each data acquisition, the femoral tracker should move a minimum of 20 mm to get better results. A judicious positioning of the leg at each step is important.

[021] The position sensing system may be of the type that automatically registers instantaneous positions

periodically. In that case, the surgeon stays in a static position for a minimum amount of time while the system registers a plurality of readings. The position is then determined by taking an average of all of the instantaneous positions that are within a certain range. When the range changes by a large amount, the system detects the change in position and does not include the readings in the average.

[022] Alternatively, the system reacts to user input to register a position reading. In that case, the surgeon places the bone in a static position and enables the system to register the position. This can be done a variety of ways, such as clicking a button on a mouse or keyboard.

[023] The large sphere in figure 2 represents the center of the femoral head. Several views are provided by the display, such as frontal, medio-lateral, and axial. The pattern of the rotation is registered and the center of rotation is identified as the center of the femoral head. After a registration tool is used to digitize the entrance point of the mechanical axis in the femur bone, a stretchable line that originates at the center of the sphere and moves with the registration tool represents the mechanical axis. This feature allows the user to correct the location of the femoral mechanical axis by clicking on the mechanical entrance point and changing its position. This axis is used as the main axis of the reference system. Figure 3 shows the user interface displaying the center of the femoral head, the

mechanical axis entrance point, and the thin cylinder that represents the axis. The entry point of the mechanical axis should be defined as the entry point of the intra-medullary rod. The mechanical axis will then be used as the main axis of a coordinate system, which will be used to provide numerical values during navigation. The user can re-enter the entry point of the mechanical axis, as many times as desired, and the system will update the axis.

[024] The next operation is the digitizing of the epicondyles, as can be seen in figure 4. Two points are used to describe a 3D axis by digitizing the epicondyles using the registration tool. The line formed between the epicondyles represents the epicondylar axis. The user can easily modify the two endpoints at any moment. The epicondylar axis is used as the second axis of the reference system and is required to provide axial numerical information during navigation. To facilitate the identification of the epicondyles, a MOSAIC™ pointer could be used to reconstruct them. This pointer is illustrated in figure 6 and will be described in more detail below. After having reconstructed the epicondyles, the user can re-digitize the landmarks more accurately.

[025] Surface model reconstruction is a process that allows the user to digitize small surfaces instead of points only. These surfaces can be small circles, as can be seen from figure 5. The small circle is physically present on the tip of the registration tool as a small,

flat disc. The size of the disc (radius) is chosen as a compromise between accuracy and time. It is counter-productive to ask a surgeon to take hundreds of points when digitizing the surface of a bone. However, the more points taken, the better the representation of the bone and the more accurate the model. The size can also vary depending on the morphology of the bone surface, affecting the precision of the tool. For example, the disc could cover an area of $1cm^2$. The disc must be flat on the surface to register as much surface as possible. The tool also registers the normal at the point of contact between the flat disc surface and the bone. As each digitized surface is registered, it appears on the output display. A sufficient amount of digitized surfaces will represent an approximate model of the entire surface. The model is formed as a mosaic of circular surfaces. This reconstruction is done in real time.

[026] From the input data gathered, the approximate model reconstruction can be morphed into an actual three-dimensional model. Once this reconstruction is done, tools used for the surgery can be tracked with respect to this model, thereby allowing the surgeon to navigate with tools and have a reference in the body.

[027] Figure 6 is the preferred embodiment of the digitizing tool, the pointer, to be used in the digitizing process. The tool is equipped with a position-sensing device, such as those known in the field of tracking, having three position identifying devices. In this embodiment,

both ends of the tool can serve as a digitizing tip, each end having a different radius. The smaller end can be used on anatomical surfaces that do not easily accommodate the flat surface of the tool. The larger end can be used on flatter anatomical surfaces. The user selects on the computer which end is used. Alternatively, there can be automatic detection of the end being used, such as the computer recognizing the radius of the disc surface when it is placed on the bone surface. For the actual registration of the small surfaces, this can be achieved in several ways. For example, there can be a button on the tool that controls the digitizing. Alternatively, this can be done by pressing a key on a keyboard to select a point to be digitized. Also alternatively, digitizing can be triggered by a rotating action of the tool by a quarter turn. It can be appreciated that alternative embodiments for the registration tool are possible. For example, other multi-purpose combinations can be made. One end can be an awl, a screwdriver, or a probe, while the other end is a digitizer. Similarly, the tool can be a single-ended digitizer as well.

[028] It will be understood that numerous modifications thereto will appear to those skilled in the art. Accordingly, the above description and accompanying drawings should be taken as illustrative of the invention and not in a limiting sense. It will further be understood that it is intended to cover any variations, uses, or adaptations of the invention

following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features herein before set forth, and as follows in the scope of the appended claims.